REMARKS

Review and reconsideration on the merits are requested.

Election/Restrictions

The Examiner correctly presents the election.

Claim Objections

Claim 3 is canceled mooting the rejection.

Claim 21 is corrected.

Withdrawal is requested.

The Prior Art

U.S. Patent Publication 2003/0134493 Cho et al.(Cho); U.S. Patent Publication 2002/0046693 Kiyoku (Kiyoku); U.S. Patent 6,773,504 Motoki et al. (Motoki).

Claim Amendments

Applicants limit claim 1 not only by combining claim 7 therewith but also by inserting the phrase "said variations in the carrier concentration lying in a surface (in-plane) thereof" after the last end of the recitation in the amended characterizing clause thereof to make amended claim 1, on which claims 2, 13 and 17-24 are dependent, respectively, changing independent claim 2 to be dependent from claim 1, and canceling claim 4, 6 and 8 from the pending claims due to the amendments to claims 1 and 2 while changing the dependency of claims 13 and 17-24 from "claim 1" to --claim 1 or 2--, as well as rewriting claim 10 to independent form with the insertion of the phrase "said variations in the carrier concentration lying in a surface (in-plane) thereof" after the last end of the recitation of the characterizing clause thereof, on which new claim 46 reciting the features of claim 2 is dependent, and new claims 47-55 reciting the features

of claim 13 and 17-24 dependent from claim 10 or 46, respectively, and canceling claim 11, due to the amendments to claims 2 and 10 and the cancellation of claims 4 and 6. With the above amendments, claim 7 has been canceled. The withdrawn claims are also canceled.

In amended claims 1 and 10, the phrase "said variations in the carrier concentration lying in a surface (in-plane) thereof" finds support at page 6, line 27 to page 7, line 2; and page 7, line 27 to page 8, line 4 of the specification.

Significant Features of the Invention

As a first point, the present invention is based on the finding that when the carrier concentration in a substrate surface (in-plane) of the outermost surface of a semiconductor substrate is allowed to be uniform, specifically when the substrate has a carrier concentration of 1×10^{17} cm^{-3} or more, variations in the carrier concentration in the surface (in-plane) are preferably within ± 25%, and when the substrate has a carrier concentration of less than 1×10^{17} cm^{-3}, variations in the carrier concentration are preferably within the ±100% in a surface (in-plane). These major features of the present invention are recited in claim 1 and in claim 10, and are hereafter referred to as the ± 25% uniform concentration aspect and the ± 100% uniform concentration aspect.

As described in detail in the specification at pages 4-5, the present invention is based on the finding that a nonuniform carrier concentration in a surface (in-plane) of a substrate which results when a III-V nitride semiconductor crystal is allowed to grow on a crystal .growth interface of the substrate by a conventional method leads to heretofore unsuspected problems.

The Inventors found that the self-supported GaN substrate produced by conventional methods has a nonuniform carrier concentration on its surface despite a lowered dislocation density, as described in the specification t page 4, line 15 to page 5, line ___ stating that:

> "In the self-supported GaN substrate, however, there may be locally nonuniform regions in the carrier concentration because an epitaxially grown thick crystal layer is used as the substrate. When crystal growth is carried out while forming facets in a growth interface, to lower the dislocation of the self-supported GaN substrate, there inevitably occurs difference between facet planes and other planes, resulting in different rates of crystal growth and thus differences in effective segregation coefficients of impurities therebetween, which leads to the nonuniform impurity distributions, namely variations in the carrier concentrations. Because regions with different carrier concentrations appear as the hysteresis of facet-grown regions, they are distributed such that they extend in a crystal growth direction. If the regions with different carrier concentrations reached the top surface of the substrate, variations in the carrier concentration would inevitably occur on the top surface of the substrate (see page 4, line 15 to page 5, line 1 of the specification),"

It was also found that when there are regions having nonuniform carrier concentrations on the surface of the GaN substrate, epitaxial GaN layers grown on such regions are prone to have high surface roughness. Even if an underlying GaN substrate is mirror-polished, the phenomenon occurs that the resultant epitaxial layer has a rough surface. Without an epitaxial GaN layer having a uniform surface morphology, the characteristics of devices formed thereon suffer from deterioration, variations, etc. (see page 5, lines 5-9 of the specification). The Inventors were first to appreciate this aspect of the present invention.

These problems have been solved by the present invention in such a manner that a carrier concentration in a substrate surface (in-plane) of the outermost surface of the substrate is allowed to be uniform, that is, when the substrate has a carrier concentration of 1 x 10^{17} cm^{-3} or more, variations in the carrier concentration lying in a surface (in-plane) are preferably within ± 25%,

and when the substrate has a carrier concentration of less than 1 x 10^{17} cm^{-3}, variations in the carrier concentration are preferably within ± 100% in a surface (in-plane).

The self-supported III-V nitride semiconductor substrate of the present invention is produced by an unconventional crystal growth process where in the course of crystal growth of a III-V nitride semiconductor crystal the growth interface is made to become flat. This aspect of the invention is explained in specific examples as production measures to obtain a new III-V nitride semiconductor substrate as described in the specification of the present application at page 7 and shown in Fig. 2(e), Fig. 7(g), Fig. 8(g), Fig. 9(f) and Fig. 11(e) of the . specification, followed by growing the III-V nitride semiconductor crystal while maintaining the state of the flatness (see page 7, lines 12-26 of the specification).

Cho

Cho discloses a method for producing doped gallium nitride (GaN) substrates, which comprises irradiating **undoped** GaN substrates with a thermal neutron flux that produces isotopes of gallium (Ga). The **doped** GaN substrates are produced when the isotopes of Ga transmute into germanium (Ge); one then thermally anneals the doped GaN substrates (see claim 1 of Cho).

Cho does not teach or suggest the present invention and is silent as to a uniform surface carrier concentration distribution not only in the substrate, that is, in a direction perpendicular to a substrate surface or in a surface (in-plane), and is also is silent as to what degree of uniformity is appropriate, that is, when the substrate has a carrier concentration of 1 x 10^{17} cm^{-3} or more, variations in the carrier concentration lying in a surface (in-plane) are preferably within ± 25%,

and when the substrate has a carrier concentration of less than 1 x 10^{17} cm^{-3}, variations in the carrier concentration are preferably within. ± 100% in a surface (in-plane).

As is clear from the flow chart given in Fig. 1 of Cho, Cho provides doped single crystal GaN substrates and GaN substrate thin films by subjecting **undoped** GaN substrates (GaN substrates with after-crystal growth prepared in advance) to **doping further** with an impurity (Neutron Transmutation Doping (NTD)) by a thermal neutron transmutation method, that is, the method includes doping the GaN material by transmuting, e. g., gallium (Ga) into germanium (Ge) using thermal neutron irradiation "fluence" 102, or a thermal neutron flux, applied to the GaN material (see paragraph [0023] and Fig. 1 of Cho).

This is an important matter, since not only is the concentration of the doped Ge controlled by the flux of the thermal neutrons to which the substrate is subjected but also doping as such is carried out uniformly in the sense that initial non-uniform carrier concentrations will not be altered by the doping. Thus, one of ordinary skill in the art could not know whether or not the carrier concentration in a substrate surface (in-plane) of the outermost surface of the finally resultant substrate of Cho is uniform or not. As an illustration, if the carrier concentration in a substrate surface (in-plane) of the undoped GaN substrate before Neutron Transmutation Doping is nonuniform, it would be impossible to obtain a self-supported III-V nitride semiconductor substrate as disclosed in the present application, even if one tried to practice precise control of uniform doping by the thermal neutron transmutation method.

In this regard, even though a III-V nitride semiconductor crystal is not doped with an impurity in the crystal growth process of a III-V nitride semiconductor substrate, since there will always exist some inevitable impurities in a furnace for the crystal growth thereof in the

conventional method, inevitable impurities as such are doped thereinto to cause a nonuniform carrier concentration in a surface (in-plane), thereby making it impossible to obtain the III-V nitride semiconductor substrate of the present invention.

Kiyoku

Kiyoku discloses a method of growing a nitride semiconductor crystal which has very few crystal defects and can be used as a substrate. The Kiyoku method includes the step of forming a first selective growth mask on a support member including a dissimilar substrate having a major surface and made of a material different from a nitride semiconductor. The first selective growth mask has a plurality of first windows for selectively exposing the upper surface of the support member. One grows nitride semiconductor portions from the upper surface of the support member, which is exposed by the windows, using a gaseous Group 3 element source and a gaseous nitrogen source. Growth continues until the nitride semiconductor portions grown in adjacent windows combine with each other on the upper surface of the selective growth mask (see Abstract of Kiyoku).

However, Kiyoku in no fashion suggests the present invention, and is silent not only regarding a uniform surface carrier concentration distribution but is also completely silent regarding the ± 25% uniform concentration aspect and the ± 100% uniform aspect earlier discussed.

The Examiner states in the paragraph bridging pages 314 of the Action that the method employing by Kiyoku is substantially similar to the Applicant's 'Example 5' method. However, the Examiner's statement is not correct. Major distinguishing features of the method for producing the III-V nitride semiconductor substrate described in Example 5 of the present

application lie, as mentioned previously, in making the growth interface become flat in the course of the crystal growth process of a III-V nitride semiconductor crystal, followed by growing the III-V nitride semiconductor crystal while maintaining a state of the flatness, Kiyoku is completely silent upon the above matters. Accordingly, Applicant submits it is quite clear that Kiyoku in no fashion suggests any of the properties of the III-V nitride semiconductor substrate of the present invention as claimed.

The Examiner also states at page 4, lines 5-6, of the Action that Kiyoku discloses forming the nitride substrate with no dopants, which then has a substantially uniform dopant concentration of 0. This statement is also not correct. The Examiner's attention is directed to the earlier discussion regarding Kiyoku, i.e., even if a III-V nitride semiconductor crystal is not intentionally formed with an impurity in the crystal growth process of a III-V nitride semiconductor substrate, there will always exist some inevitable impurities in the furnace and the substrate will be doped with such inevitable impurities.

The Examiner further states at page 4, lines 2-4, of the Action that Kiyoku discloses that the upper layer 17 or 116 are made substantially defect free, and thus, should not exhibit variances in carrier uniformity resulting from pitting of the layer.

Applicant's respectfully submit that this is not correct since when crystal growth is carried out to achieve a "no defect" interface or to lower dislocations of a self-supported gaN substrate, this will inevitably lead to non uniform impurity distribution, namely variations in carrier concentration. See the specification at page 4, lines 15-24 earlier quoted herein.

Motoki

Motoki discloses an oxygen doping method for a gallium nitride single crystal substrate which method comprises the steps of: preparing a non-C-plane gallium nitride single crystal seed having a surface except for a C-plane, supplying the non-C-plane gallium nitride seed with growth gases including a gallium material, a nitrogen material and an oxygen material without silicon, growing a gallium nitride bulk crystal upon the non-C-plane gallium nitride seed in the vapor phase, maintaining the non-C-plane surface on the growing gallium nitride bulk crystal, and doping the growing gallium nitride bulk crystal with oxygen via the non-C-plane surface (see claim 1 of Motoki).

Motoki does not teach or suggest the ± 25% uniform concentration aspect or the ± 100% uniform concentration of the present invention earlier discussed. Further, Motoki is completely silent as to a uniform surface carrier concentration distribution not only in anywhere in the substrate but also to what degree of the uniformity, that is, when the substrate has a carrier concentration of 1×10^{17} cm^{-3} or more, variations in the carrier concentration lying in a surface (in-plane) are preferably within ± 25%, and when the substrate has a carrier concentration of less than 1×10^{17} cm^{-3} , variations in the carrier concentration are preferably within ±100% in a surface (in-plane).

Embodiment 1 shown in Fig. 2(a) to Fig. 2(d) of Motoki only teaches crystal growth of a gallium nitride crystal on an M-plane GaN seed crystal by an HVPE method (see column 13, lines 36-67 of Motoki), and, accordingly, Motoki fails to disclose a method for obtaining the self supported III-V nitride semiconductor substrate of the present invention as shown in the Examples of the present application.

Further, Embodiment 2 shown in Fig. 4(a) to Fig. 4(d) of Motoki teaches crystal growth of a faceted GaN crystal on a C-plane GaN seed by an HVPE method (see column 15, line 63 to column 16, line 42 of Motoki), which corresponds to the conventional method which was earlier discussed in this AMENDMENT.

The rejection of claims under 35 U.S.C. § 102(e) based on Cho.

Claims 4, 6, 7, 8 and 11 have been either withdrawn or canceled from the pending claims.

Amended claim 1 herein calls for: "A self-supported III-V nitride semiconductor substrate having a substantially uniform carrier concentration distribution at least on its outermost surface, wherein said substrate has a carrier concentration of 1×10^{17} cm^{-3} cm or more, and wherein variations in the carrier concentration are within ± 25% in said outermost surface, said variations in the carrier concentration lying in a surface (in-plane) thereof." These aspects of the present invention are nowhere suggested or discussed in Cho.

The reason for this is Cho does not teach or suggest a uniform surface carrier concentration distribution not only in anywhere in the substrate, for example, in a direction perpendicular to a substrate surface or in a surface (in-plane), but also fails to teach what degree of the uniformity It is required, i.e., in no fashion is the ± 25% uniform concentration aspect or the ±100% uniform concentration aspect of the present invention suggested in Cho.

Accordingly, it is submitted the claims are not properly rejected as anticipated by Cho.

With respect to the remaining claims which depend from claim 1, Applicant relies on the above arguments.

Amended claim 10 herein calls for: "A III-V nitride semiconductor substrate having a substantially uniform carrier concentration distribution at least on its outermost surface, wherein

said substrate has a carrier concentration of less than 1 x 10 cm, and wherein variations in the carrier concentration are within ± 100% in said outermost surface, said variations in the carrier concentration lying in a surface (in-plane) thereof"

One distinguishing feature of amended claim 10 is found in the variations in the carrier concentration lying in a surface (in-plane) thereof. The features of amended claim 10 are different from those of Cho. As earlier discussed, i.e., Cho in no fashion suggests the ± 100% uniform concentration aspect of the present invention.

The rejection of claims under 35 U.S.C. § 102(b) based on Kiyoku.

Claims 4, 6, 7, 8 and 11 have been either withdrawn or canceled from the pending claims.

Kiyoku has earlier been discussed in detail. Kiyoku is completely silent regarding a uniform surface carrier concentration distribution in the substrate, and certainly contains no suggestion of a uniform carrier in a surface (in-plane). Finally, Kiyoku in no fashion teaches that when the substrate has a carrier concentration of 1 x 10^{17} cm^{-3} or more, the ± 25% uniform concentration aspect of the present claims must be met.

Accordingly, Applicant submits that claim 1 of the present application is not anticipated by Kiyoku.

For claims depending from claim 1, Applicant relies upon the above arguments.

With respect to claim 10, in a manner similar to the earlier remarks, Kiyoku in no fashion suggests the ± 100% uniform concentration aspect of the present invention. Accordingly, claim 10 is not properly rejected as anticipated by Kiyoki.

The rejection of claims under 35 U.S.C. § 102(e) based on Motoki.

Motoki has earlier been discussed in detail. As discussed, Motoki is silent regarding any uniform surface carrier concentration distribution in a substrate and certainly does not teach in a direction perpendicular to the substrate surface or in a surface (in-plane), and fails to suggest the ± 25% uniform concentration aspect of the present invention earlier discussed.

Thus, Applicant submits that claim 1 is not properly rejected as anticipated by Motoki.

With respect to claims which depend from claim 1, Applicant relies on their earlier argument.

Withdrawal of all rejections/objections and allowances requested.

In view of the above, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby solicited. If any points remain in issue which the Examiner feels may be best resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

The USPTO is directed and authorized to charge all required fees, except for the Issue Fee and the Publication Fee, to Deposit Account No. 19-4880. Please also credit any overpayments to said Deposit Account.

Respectfully submitted,

/Peter D. Olexy/
Peter D. Olexy
Registration No. 24,513

SUGHRUE MION, PLLC
Telephone: (202) 293-7060
Facsimile: (202) 293-7860

WASHINGTON OFFICE
23373
CUSTOMER NUMBER

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